7 Total Station Survey System (TSSS) Survey Specifications

Survey specifications describe the methods and procedures needed to attain the desired survey standard. Specifications in this section are based on Federal Geodetic Control Subcommittee (FGCS) standards and specifications. Except where noted, they have been modified to give results that will meet the standards for various types of TSSS surveys typically performed by Caltrans. For complete standards, refer to Section 5, "Accuracy Classifications and Standards".

Caltrans TSSS survey specifications are to be used for all Caltrans-involved transportation improvement projects, including special-funded projects.

7.1 The TSSS Method

The TSSS is a system that includes an electronic theodolite, electronic distance measuring instrument (EDMI) and electronic data collecting system. Conventional survey methods of traverse, network, resection, multiple ties and trigonometric leveling are used with the TSSS system. Each Caltrans field crew is equipped with a TSSS. The basic specifications for the Caltrans TSSS are:

- Electronic Theodolite: one second, σ = 0.5" (σ = standard deviation)
- EDMI: σ = 3 mm $\pm$3 ppm, in standard measurement mode
  Range – 2500 m to one prism
- Data Collector: MS-DOS, 1 megabyte RAM
- Software: Caltrans Data Collection Software (CTDC)

The system also includes tripods, tribrachs, prisms, targets and prism poles.

For specific questions about the use of CTDC, see the *CTDC Manual*, available from the Geometronics Branch.

The specifications included in this Section are based on the basic Caltrans TSSS. If other TSSS are used, these specifications might not be applicable.

All TSSS equipment must be properly maintained and regularly checked for accuracy. Equipment repair, adjustment, and maintenance is covered in Section 3, "Survey Equipment."

7.2 General TSSS Survey Specifications

7.2-1 Redundancy

When proper procedures are followed, the Caltrans TSSS generally can easily meet the accuracy standards for Caltrans second-order, third-order, and general-order surveys. For example, the Caltrans TSSS instrument specifications indicate that angles observed one time would meet the required accuracy standards, but without redundancy of observations, the possibility of blunders exist. For this reason, a complete set of angles is observed (two direct observations and two reverse) whenever establishing or tying existing critical points such as control points and land net points. Redundant observations such as multiple ties should be observed whenever feasible to improve the information available from least squares adjustments and to strengthen survey networks.

7.2-2 Equipment Checks

Total station vertical index and horizontal collimation should be checked each day.

Systematic errors due to poorly maintained equipment must be eliminated to ensure valid survey adjustments. Optical plummets, tribrachs, tripods, and leveling bubbles should be checked and adjusted regularly. Barometers and thermometers should be checked regularly for accuracy. Equipment acquisition, repair, adjustment, and maintenance is covered in Section 3, "Survey Equipment."

7.2-3 Set Up

Height of instrument and target: Measure and enter the H.I. and H.T. into the data collector at the beginning of each set up. It is advisable to check target and instrument heights at the completion of each set up along with the optical plummet's position over the point.

Temperature and barometric pressure: Measure and enter the appropriate ppm correction into the total station before work is begun each day for general-order and third-order surveys. For second-order surveys, temperature and pressure readings should be made and ppm correction entered into the total station again at midday. Each 1°C change in temperature will cause a one ppm error, if the ppm setting in the total station is not changed.

Checking: After setting up, measure the distance to the backsight to provide a check. Observations of other known points are encouraged whenever practical. For general-order surveys, it is good practice to observe selected points from two set ups as a check. At the conclusion of each set up, the direction to the backsight should be reobserved. For general-order surveys (construction staking, topographic surveys, etc.), areas surveyed from two different set ups should have common points from the two set ups to provide additional checks.

Mode: All distance observations are taken in standard measurement mode on the total station.

7.2-4 Field Notes

Original survey notes for all TSSS observations are maintained in the data collector and are kept on disk in the form of a .dmp file. Data collector headers should be fully filled in and comments about observations that could affect data reduction should be added to the data collector file with a text entry. Data for all points that will be used as control (topo code series 100) and any land net property corners (topo code series 3000) must be collected as foresight observations not radial observations in the data collector, as only foresight data is available for least squares adjustment.

Hand-written survey notes should be used to supplement the data collector notes. At a minimum, these should include sketches, detailed descriptions and/or rubbings of monuments as appropriate and other general comments about the survey.

Field notes are not considered complete until the title page is stamped and/or signed and sealed by the Licensed Land Surveyor in responsible charge of the work.

For details regarding field notes see Section 14, "Survey Records."

7.2-5 Survey Adjustments

All control points used for data gathering and stake out, including photo control, shall be adjusted by the method of least squares. Resected control points are adjusted for horizontal position by least squares before they are used in the field.

See Section 5.4, "Least Squares Adjustment."

7.3 Second-Order Surveys

7.3-1 Applications

Corridor Control: TSSS can be used to perform second-order trigonometric leveling surveys for Corridor Control Surveys (California High Precision Geodetic Network Densification – HPGN-D).

Project Control: TSSS can be used for horizontal and vertical Project Control Surveys to densify project control established by GPS.

7.3-2 Horizontal Specifications

Method: Traverse with cross-ties.

Table 7-1 lists the specifications required to achieve second-order horizontal accuracy.

7.3-3 Vertical Specifications

Method: Trigonometric Leveling

Table 7-2 lists the specifications required to achieve second-order vertical accuracy.

Note: For specifications for second-order trigonometric leveling acceptable to the National Geodetic Survey (NGS), see *Interim Specifications for Trigonometric Leveling, Second Order, Class II, National Geodetic Survey* – Caltrans, August 4, 1993. All second-order trigonometric leveling surveys submitted to NGS must conform to these specifications.

Table 7-1 Second-Order (Horizontal) TSSS Survey Specifications

Specifications	Traverse/Network
Check vertical index error	Daily
Check horizontal collimation	Daily
Measure instrument height and target height	Begin and End each setup
Use optical plummet to check position of target and instrument over points	End of each setup
Measure temperature and pressure and enter ppm correction into total station	First setup, midday setup
Measure distance to backsight and foresight at each setup	Required
Observe traverse multiple ties to improve least squares adjustment	As Feasible
Close all traverses	Required
Horizontal angle observations	2D, 2R
Vertical angle observations	2D, 2R
Angular rejection limit, i.e., reject if difference from mean of observations is greater than	10"
Minimum distance measurement	100 m

Table 7-2 Second-Order (Vertical) TSSS Survey Specifications

Specifications	Trigonometric Leveling
Check vertical index error	4 times per day
Use fixed height tripod	Required
Use fixed height staff for target	Required
Measure temperature and pressure and enter ppm correction into total station	First setup, midday setup
Vertical angle observations	2D, 2R *(See Note)*
Angular rejection limit, i.e., reject if different from mean of observations is greater than	10"
Measure uncorrected zenith distance	Each pointing
Measure uncorrected slope distance	Each pointing
Difference between two differences in elevation for each setup not to exceed	1.5 mm
Maximum sight length	70 m
Minimum ground clearance of line of sight	1 m
Difference between backsight and foresight lengths not to exceed	10 m

Note: Two sets; each set of observations (2D, 2R) yields an independent difference in elevation between the backsight and foresight.

7.4 Third-Order Surveys

TSSS can be used for both third-order horizontal and vertical positioning.

7.4-1 Applications

- Supplemental Control Surveys for Construction and Engineering Surveys
- Photogrammetric Control
- Land Net Location Control
- Monumentation Control
- Major Structure and Interchange Staking

Supplemental control points are points that will be used as set-up points to gather topographic data, locate land net monuments, perform Construction Staking and set-out other control and R/W monuments.

7.4-2 Specifications

Methods

- Traverse
- Resection: This method locates the unknown position of a set-up point by observing known positions from the unknown set-up point. Data for resected points are collected as foresight observations. Generally, points should be resected by observing three known points of equal or greater accuracy. Two point resections may be acceptable if the angle between the observed points is less than 135 degrees or greater than 225 degrees. All specifications for third-order must be met. Review the "Coordinate Summary Report" in the Caltrans Data Collection (CTDC) program to verify that resected points meet accuracy standards.
- Multiple Tie (Intersection): This method locates points of unknown position by observing the points from two or more control points. These observations must be collected as foresight observations not as radial observations. CTDC statistics should be reviewed to ensure that the positions of unknown points meet minimum accuracy standards.

Table 7-3 lists the specifications required to achieve third order accuracy.

Table 7-3 Third-Order TSSS Survey Specifications

Specifications	Traverse/Network Resection Double Tie
Check vertical index error	Daily
Check horizontal collimation	Daily
Measure instrument height and target height	Begin and End each setup
Use optical plummet to check position of target and instrument over points	End of each setup
Measure temperature and pressure and enter ppm correction into total station	First set-up of day
Measure distance to backsight and foresight at each setup	Required
Observe traverse multiple ties to improve least squares adjustment	As Feasible
Close all traverses	Required
Number of known points to observe	N/A
Horizontal angle observations	2D, 2R
Vertical angle observations	2D, 2R
Angular rejection limit, i.e., reject if different from mean of observations is greater than	10"
Minimum distance measurement to meet horizontal standard	50 m
Maximum distance measurement to meet vertical standard	100 m

Table 7-4 General-Order TSSS Survey Specifications

Specifications	Radial
Check vertical index error	Daily
Check horizontal collimation	Daily
Measure instrument height and target height	Yes
Use optical plummet to check position of target and instrument over points	Begin and End each setup
Measure temperature and pressure and enter ppm correction into total station	First setup of day
Horizontal angle observations	1D
Vertical angle observations	1D
Minimum distance measurement to meet horizontal standard	20 m
Maximum distance measurement to meet vertical standard	150 m

7.5 General-Order Surveys

7.5-1 Applications

- Engineering Survey collected topo data
- Construction Survey, staked points
- GIS Surveys
- Environmental Surveys

See Section 12, "Engineering Surveys" and Section 13, "Construction Surveys" for tolerances and accuracy standards for specific types of surveys.

7.5-2 Specifications

The radial survey method is used for all general-order surveys. Data for general-order points are gathered as radial observations in the data collector and are not available for least squares adjustment.

For construction staking, staked positions are rejected, when the difference between the "set" (observed) position and the theoretical design position exceeds the allowable tolerance. See Section 13, "Construction Surveys" for tolerances

Engineering survey data points are checked by various means including reviewing the digital terrain model, reviewing data terrain lines in profile, and redundant measurements to some points from more than one setup.

Table 7-4 lists the specifications required to achieve general-order accuracy.